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MONDAY, DECEMBER 11, 1865.

THE VERY REV. CHARLES GRAVES, D. D., President, in the Chair.

Mr. W. H. Hardinge read a paper "On the Irish Transplantation of A. D. 1653–54; and on the Extent, Value, and Distribution of the Lands forfeited in Ireland."

Mr. W. HANDSEL GRIFFITHS read the following paper:—

ON HÆMODROMOMETERS.

THERE has long been a question among physiologists as to the velocity with which the blood moves in the arteries. Many of them have made calculations which, had they come from others than men of such repute, would have excited derision; and indeed we can scarcely refrain from smiling when we read that Hales "inferred the velocity of the blood at the commencement of the aorta in man to be at the rate of 735 feet per second."

The celebrated Volkman saw the folly of the deductions drawn from such vague data as these were, and he devised an instrument, which he termed the "Hæmodromometer," the object of which was to *measure* the velocity of the movement of the blood in the arteries.

The results of experiments made with this instrument were, of course, much more reliable than those founded on calculations inferred from data of the most vague and uncertain character; but, while I would unhesitatingly give the preference to the deductions drawn from experiments with Volkman's Hæmodromometer, I can by no means assent to the supposition that they are correct, *or even nearly so*. The use of Volkman's instrument involves great objections; and, although I look on the instrument itself as a model of ingenuity, I cannot regard it as one on which I should depend for a solution of the problem, With what velocity does the blood move in the arteries?

I will proceed to describe as briefly as possible the construction and mechanism of Volkman's Hæmodromometer. I will then consider the objections which I entertain to it; and it is but right that I should afterwards mention how I would propose to rectify these defects.

Volkman's Hæmodromometer consists essentially of a glass tube, which is bent into the form of a hairpin, and is fifty-two inches long. This tube is filled with water; and, by a peculiar arrangement, is placed between the open ends of a cut vessel. For a concise description of this instrument, I beg to refer to Todd and Bowman's "Physiological Anatomy," vol. ii., page 364. In the drawing which is given in that work is represented a tube, which is constructed of metal, and measures one inch and a half in length; it terminates at cones, which fit into other cones, by which means they are adapted to the cut ends of the vessel. The mechanism of the stopcock is indeed an admirable contrivance; and, although easily understood,

is rather difficult of description. The handle commands the course of the tube by means of two cogged wheels, so that when it is turned in one direction it allows a free passage *directly* from one end to the other; and when it is turned in the opposite direction *this* free passage is interrupted, and another passage, namely, from one end, *along the hairpin tube*, to the other end is opened; so that at the will of the operator he can open one communication to the exclusion of the other, but he cannot obtain a double communication. The glass hairpin-shaped tube is attached to a board, on which is fixed a scale.

When the Hæmodromometer is used, a large artery is exposed for about three inches, and a piece is cut out of it after means have been adopted for the prevention of hemorrhage. The next step is to fix the cone-shaped open cups into the open ends of the artery, and each end of the horizontal metal tube is then fitted into its corresponding cup. I should mention a precaution which it is here necessary to observe—it is this: to so arrange the distance of the cups that, when the horizontal tube is introduced between them, the *continuation of the vessels* is as little altered as possible by the intervening mechanism. The blood now continues to circulate through the horizontal tube as it would were the vessel entire, the stopcock being so turned as to shut off communication with the glass tube. This latter is now filled with water, and is fixed to the horizontal tube by means of pipes. The arrangement is now complete, and the stopcock is turned, so as to shut off the *direct* communication between the two ends of the horizontal tube. The blood now enters the glass tube, and pushes the water before it into the peripheral blood vessels, with (according to Volkman) only a very slight admixture between the two fluids.

I have now described at length this very ingenious instrument; and it would seem at first that it supplies what is needful, in every respect, and that the results obtainable from experiments with it are very reliable. On mature consideration, however, no one will fail to perceive that there *are* grave objections to it; and it now devolves upon me to mention those which have struck me as being most prominent. There are one or two of these objections which I myself have not succeeded in obviating; and many will say that it were well that I should pass over these, and confine myself to such as I *can* remove. Were I to heed such suggestions, I should not be performing the duty I have taken on myself; for, although the instrument which I am about to describe I believe to have many advantages over that of my brother physiologist, no one is more sensible of the fact than I am that it is by no means a perfect instrument, and that it is itself open to great objections—objections which I do not despair of being able to remove at some future period, or which, I myself being incompetent, will I doubt not be done away with, and that right speedily, through the exertions of the learned physicists and physiologists to whose notice I submit them. Thus, in mentioning objections to Volkman's Hæmodromometer which baffle my own inventive faculties to remove, I anticipate the defects of my own instrument.

The first objection which I have to state to Volkman's Hæmodromometer is applicable to mine also—it is that of *the sudden propulsion of the blood from a tube of elastic and contractile force into one perfectly inelastic, and one not having muscular force.* The effect of this condition is more serious than is generally imagined; for when the natural calibre of the *artery,* or its caliber *when not in the distended state,* corresponds with that of the *glass tube,* the former is capable of receiving a greater quantity of blood than the latter; and the contractility called into action by this expansion is now exerted, and contributes to quicken the velocity of the remaining fluid. No such conditions as these exist in the glass tubing; and the only plan I have adopted, with a view to lessen this difference between the two tubes, is to use a glass tube whose caliber will be equal to that of the artery when at a moderate expansion.

The second objection is one which, although I have considerably lightened, I have not been able entirely to meet, namely, the *existence of sharp turns in the long glass index tube.* In Volkman's instrument there are three of these sharp turns; one at the entrance, and another at the exit, both of which are right-angled; the third is situated in the centre of the tube, and is in reality made up of two turns, each of which is right-angled also; the *effect* is alleviated in the latter case by the curves being well directed; but in the former cases, namely, at entrance and exit, the arrangement is directly angular. I need not say how detrimental to the velocity of a running fluid the presence of these angles is, nor need I explain how the column of blood which is being propelled into the tube, meeting at its entrance an opposing wall has to be reflected, as it were, from it before it pursues its course. The same takes place at the exit of the tube, except that here the reflection, if I may be allowed the term, takes place in an opposite direction; so that, instead of the fluid being prevented to a degree from entering the tube, it is here hindered in leaving it—not *altogether,* of course, but in a degree to affect considerably the velocity of the movement of the contained fluid. At the centre of the tube, also, is a sharp turn, arranged so that the fluid arriving by one limb of the tube has to be sent back immediately after moving round this sharp double turn in the opposite direction. My instrument must be regarded as of much better design in respect to *curves in the tube* than that of Volkman; for, while the fluid entering into his is immediately sent in a direction at right angles to the course, the direct course of mine is interrupted but very little. The curves in my Hæmodrometer are greatly exaggerated, and the caliber of the tube where they exist is slightly increased.

The third objection which I would urge is *the sudden propulsion of hot blood from a vessel of a certain temperature into another of a much lower degree of heat, or almost cold.* This defect would seem to be of such trivial consequence as to warrant its being entirely overlooked. The experiments which I have made touching this question, however, induce me to insist on the above as a decided objection. I have seen that when blood or any other fluid is heated to a certain point, and is passed through a vessel of a certain temperature, and when, after

traversing this tube for a certain distance, it is then made to pass through another tube continuous with the first, but cooled to or below zero, the velocity of the running fluid is diminished from that which was maintained in the heated tube. The manner in which I have sought to remedy this evil is the following :—The flat support, to which is attached the essential part of the instrument, is made so as to contain two moveable iron heaters; when these are removed, and heated, and then sent home into their respective cavities, the warmth they contain is communicated first to the copper support, and thence to the glass tube, through which the blood courses.

The next objection refers rather to the mode of using the Hæmodromometer than to the instrument itself. Volkman's apparatus was, you will remember, filled with *water* previously to operating. Now, no one will refuse to recognise the inadvisability of the blood having to meet a fluid of a very different specific gravity from itself, and one, moreover, whose total immobility it has to overcome ere it can itself move an inch. I look upon this as a most serious objection to Volkman's mode of estimating the velocity of movement of fluid in a tube; and indeed Volkman himself would seem to have anticipated that the validity of his method would be called into question on this account, since he takes care to inform us that the water is moved into the peripheral arteries with but little admixture with the blood. I can only say that I have put Volkman's statement to the test of *experiment*, the most reliable criterion, and I have invariably found the mixture of the two fluids to be most considerable, and the specific gravity of the resulting mixture to vary much from that of either the blood or water. When using my instrument, I apply one end of the tube to the cut end of the artery whence the blood flows, and I apply suction at the other end, so as to create a vacuum, into which the flood flows freely. When it has arrived at the opposite end, having turned the stopcock, I remove the ligature which had been placed on the peripheral end of the artery, and introduce the end of the tube into that of the vessel; and the blood flows, on again turning the stopcock, as though it experienced no interruption whatsoever. Of course, these latter operations should be performed as quickly as possible; and, in order to avoid the trouble of tying and untying ligatures, I make use of a minute forceps—one which on pressing with the fingers opens, and on removing the pressure closes with a tight grip.

I have now mentioned the four great objections which I have to Volkman's Hæmodromometer: each one of them *tends to decrease the velocity of the blood's movement; and hence, when we consider the combined effect of these, we must allow that the results of experiments made with this instrument are not such as can be relied upon, nor do they correctly estimate the velocity with which the blood moves in the arteries.*

It now behoves me to describe a Hæmodromometer which I would propose as a substitute for Volkman's; and I must confess that I feel considerable diffidence in so doing, not because I myself doubt for one instant the superiority of my instrument as far as regards accuracy, but

since I feel it to be presumptuous in me to offer aught to the scientific world intended to compete with the productions of so learned a physicist and physiologist as Volkman. My duty, however, prompts me not to yield to such feelings; and so, with a firm conviction of its worth, I proceed to the description of my Hæmodromometer. In my description I beg to refer to the diagrams, such as they are, which I have drawn, in order to render the details more intelligible.

The complete instrument, as seen in the drawing (Fig. 1), consists of the copper support, to which is attached, by means of the fasteners

Fig. 1.

(*a*, *a*, *a*), the glass index tube, furnished with its arrangements of stop-cock (*b*), and piston (*c*). The free extremities of the glass tube extend slightly beyond the support, so as to be more readily connected with the cut ends of the artery. Near the centre of the support is a chronometer, the hand of which describes the circle in one minute. At one side of the support are represented the heaters (*e*), which are sent home into their respective cavities.

The shape and construction of the support will be readily seen on glancing at the diagram. It is made of copper, which is a very good conductor of heat. At its side are the openings of the two cavities, which extend longitudinally along it for about three-fourths of its length; into these cavities run the iron heaters, furnished with handles of porcelain, so as not to burn the hands of the operator when they are to be removed from the fire. The heaters are kept in their position in the support by means of a long iron pin, which runs through a hole in the support and heaters, as seen in the drawing (*f*).

The index tube will be seen to have a peculiar form; and, simple as this form looks, it has cost me much thought and consideration to determine on it as being that which would be least likely to prove detrimental to the flow of fluid in it.

This tube will be observed to have no sudden angles in its course. The fluid on entering into it is *not* met by an opposing wall, as in Volk-

man's instrument, nor is it immediately turned in a direction at right angles to the one it was previously pursuing; on the contrary, the deviation from the natural course is gradual, and the fluid is coaxed, as it were, round the turns in the tube, when it arrives at them. I have already mentioned that the caliber of the tube equals that of the artery when at a moderate expansion, and also that the caliber of the turns of the tube is very slightly wider than the caliber of the straight portions. I need not again repeat why these differences in caliber should exist. From the foregoing remarks you have already anticipated the necessity for having different tubes, each with a different bore, so as to be applicable in the case of variously-sized arteries. I have described to you Volkman's arrangement of cone-shaped cups for connecting his tube to the ends of the arteries. I do not recognise the necessity for this plan at all; and I believe that, if the glass tube have its termination furnished with slightly raised edges, so as to take a purchase on the artery, the desired effect is obtained just as well.

The removal from or fastening of the different tubes to the support is easily effected by opening and shutting the fasteners (Fig. 1 *e*), which are furnished with hinges and clasps.

Each tube is furnished with a piston index apparatus (*c*), and with a stopcock (*b*). The piston index apparatus (Figs. 2 and 3), consists of two tubes, the one horizontal, whose bore equals that of the glass tube, and which is continuous with it; the other perpendicular, arising from the centre of the former, and into which fits exactly a piston. This latter tube, instead of being rounded, as is the horizontal tube, is square. Where the two tubes communicate, therefore, a square orifice exists in the upper wall of the horizontal one (Fig. 4); so that, were fluid traversing this latter, it would rush up into the square perpendicular tube. The handle of the piston consists of the stem, the press, and the handle proper. The stem is of such length, that, when the piston is shut down, the press, or lower surface of it, must form a

Fig. 2.

Fig. 3.

Fig. 4.

continuous surface with the upper wall of the horizontal tube. In order to effect this continuity of surface, the press (Fig. 5) must be curved correspondingly to the wall of the horizontal tube; and it must be of such size as exactly to fit the piece which is wanting where the two tubes, horizontal and perpendicular, communicate. The whole of this mechanism is constructed of brass. The piston must be removable from its perpendicular square tube, so as to admit of the index ball, which I shall presently describe, being attached to its press. When an observation is to be made, the piston is to be taken out, together with the lid of the perpendicular square tube. To the under surface of the press is then attached lightly the index ball, which is made of gelatine. The arrangement is then placed in the position as seen in the drawing (Fig. 2), and the blood is now brought through the glass tube, the above preparations having been, of course, completed first. When the time has come for making the observation, after the blood has been circulating for a few seconds, the piston is pressed down, the spring which kept it raised is overcome, and another spring is engaged which keeps it down. The index ball is thus suddenly propelled into the current, and, being of a certain size, is carried along the tube with the same velocity as that with which the blood itself moves; the lower end of the press of the piston has at the same time formed the wanting part of the upper wall of the horizontal tube, and the blood courses without interruption. The index ball has not gone far before it comes up to a scratch (Fig. 1, *i*) on the glass index tube. As it passes this point, the operator glances at the chronometer, and notes the time; subsequently, the ball passes another scratch (Fig. 1, *j*), which is at a known distance from the former one, and immediately as it does so, the operator again consults the chronometer, notes the time, and turns the stopcock to prevent the ball from passing into the peripheral end of the artery. The observation is now completed, the index ball having passed through a certain distance in a certain lapse of time, and thus the velocity of the movement of the blood has been computed.

Fig. 5.

For a long time I was puzzled how to obtain balls of such lightness as would not affect the movement of the blood. After some consideration, I adopted the following process:—A warm concentrated watery solution of gelatine is made, and the polished extremity of an iron rod is rolled about in it, having been previously dipped in oil. The rolling having been continued for some seconds, the rod is taken out of the solution, and a thin coating of gelatine adheres to it. This coating has now to be removed from the mould, which is done by very gentle manipulation, until it is coaxed off. A small "exhauster," furnished with a sharp extremity, and with a stopcock, is now introduced into the open mouth of the gelatine ball, and, by working

with the fingers, the latter becomes tightly applied to the extremity of the exhauster, and the air is sucked out from the ball by the mouth. When it is considered that nearly all the air has been subtracted, the stopcock is turned before taking the exhauster from the mouth, and while the suction is yet going on; a little careful manipulation is now required to remove the ball from the exhauster without allowing the air to re-enter. When the operator has succeeded thus far in the manufacture of his ball, the next step is to make it as round as possible. This is effected by two "rounders" (Figs. 6 and 7), which I have sketched; these consist of polished metal; they are hollowed out slightly from centre to surface; one of them is furnished with a handle, and the other is to be laid on the table when using them. They are first heated by pouring some warm oil on the polished hollowed surface; the index ball is put on the one which is stationary, and the other "rounder" is *gently* worked over it in a circular manner until the ball has become perfectly round; the rounders are heated at intervals by adding more hot oil to their polished surfaces. I need not mention the necessity there is for iron moulds of *different* bulk, in order to produce balls of different sizes, adapted to the variously sized tubes.

Figs. 6 and 7.

I have now completed the description of my Hæmodromometer. That I do not expect it to be considered as anything like a perfect instrument, I have already said. I know that some physiologists will object to it on account of the complexity of previous operations which must be performed when working with it; but will any one, I ask, give the preference to Volkman's instrument simply because of the trouble of working which mine would cost the operator? If so—if it is desirable that instruments be made with a view rather to save the operator work, than to attain to accuracy of result—then have I laboured in vain.

The following donations were presented:—

1. From the Society of Antiquaries of London the following publications of the Society:—
   "Layamon's Brut," edited by Sir F. Madden. 3 vols.
   "Rotuli Scaccarii Normanniæ," edited by T. Stapleton. 2 vols.
   "Codex Exoniensis," edited by B. Thorpe. 1 vol.
2. From Joseph Gurney Barclay, Esq., "Astronomical Observations, 1862-64."
3. From the Commendatore Negri Cristoforo, "La Storia Antica Restituita."

The thanks of the Academy were voted to the donors.